Ain Shams University
Faculty of Engineering
Mechanical Power Department

Effect of blade's configuration on the performance of centrifugal pumps

By
Eng. Ashraf Sadek Abo El-yazed

Supervised by

Maj. Gen. Prof. Dr. Ibrahim Saleh Mostafa
Military Technical College

Prof. Dr. Raouf Nassif Abdelmassih
Faculty of Eng. Ain Shams University

Dr. Ehab Mouris Mina
Faculty of Eng. Ain Shams University

This thesis is submitted as a partial fulfillment of the requirements for the degree of Ph.D. Science in Mechanical Engineering

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Examiners Committee

Name	**Signature**
Prof. Dr\ Maher Gameel Hegazy	....
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Prof. Dr \ Ibrahim Saleh Mostafa	....
Prof. Dr \ Raouf Nassif Abdelmassih	....

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Ph.D. Thesis

Name of Researcher : Ashraf Sadek Abo El-yazed
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Supervision Committee:

1- Prof. Dr\ Ibrahim Saleh Mostafa
Professor at Military technical college
2- Prof. Dr\ Raouf Nassif Abdelmassih
Professor at the Mechanical Power Department
Faculty of Engineering - Ain Shams University
3- Dr.\ Ehab Mouris Mina
Associate Professor at the Mechanical Power Department
Faculty of Engineering - Ain Shams University

Statement

This thesis is submitted as partial fulfillment of Requirements for the Degree of Doctor of Philosophy,

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The author carried out the work included in the thesis, and no part of it has been submitted for a degree or qualification at any other scientific entity.

Signature
Ashraf Sadek Abo El-yazed

Ain Shams University
Faculty of Engineering
Mechanical Power Department

Curriculum Vitae

Name of researcher	**:** Ashraf Sadek Abo El-yazed
Date of Birth	**:** 9\8\1966
Place of Birth	**:** Khrset- Tanta - Gharbeya
First University Degree	**:** M.Sc. Mechanical Power Engineering.
Department	**:** Mechanical Power
University	**:** M.T.C.
Current job	**:** officer engineer
Signature	**:**

Abstract

Centrifugal pumps are considered as the main active part in the hydraulic systems used for liquid transportation. In the present work, the effect of changing the blade configurations of the centrifugal pump impeller on the centrifugal pump performance has been investigated.

A test rig was set up to measure the pump head, discharge, and power. The impeller of the pump under investigation was designed such that, its shape could be changed. Each of the five blades was divided into three parts. The second and the third portions of each blade could be rotated forward or backward by a step of 24 degree. The case with no rotation (continuous blade) tested as a base line reference, should be refereed to in the rest of the research as the conventional blade. Eight additional configurations resulted from rotating either or both of the movable sections, forward or backward. The change in flow rate and head associate with each case was recorded for each blade configuration and compared to the conventional case.

The performance is computed for a design speed of 1450 rpm, as well as 3 other rotational speeds, namely: 1200, 900, and 700 rpm.

Further investigation was carried using computational fluid mechanics to analyze the flow patterns through a pump with an impeller having a conventional blade configuration. The performance curve produced by the simulation satisfactory the curve obtained experimentally.

The results showed that, splitting the impeller blade's does not change the normal pump characteristics behavior of the backward-curved blade, but it affects the pump efficiency, head, flowrate, and cavitation depending on the number of splitted parts, position of splitting and the direction of rotation of the splitted parts (backward or forward).

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Contents

NOMENCLATURE

b	blade width	(m)
BP	brake power	(W)
C_H	$C_H = \frac{gH}{n^2D^2}$	
C_Q	$C_Q = \frac{Q}{nD^3}$	
D_o	eye diameter	(m)
D_1	inlet diameter	(m)
D_2	outlet diameter	(m)
D_h	hub diameter	(m)
D_{sh}	shaft diameter	(m)
D_{su}	suction diameter	(m)
G_b	generation of turbulence kinetic energy due to buoyancy	
G_k	generation of turbulence kinetic energy	
H_p	pump head	(m)
H_{design}	pump design head	(m)
I	phase current	(A)
n	pump rotational speed	(rpm)
N_p	Fluid power	(kW)
N_m	input power	(kW)
Ns	specific speed	(rpm)
P_d	pump discharge pressure	(pa)
P_s	pump suction pressure	(pa)
Q	pump flow rate	(m^3/s)
Q_{design}	pump design flow rate	(m^3/s)
R_1,R_2	ring radii	(mm)
S_s	shear stress	(N/m^2)

S_{ij}	modulus of the mean rate-of- strain tensor	
T	shaft toque	(N.m)
u_1,u_2	Tangential inlet & outlet velocity	(m/s)
u_r u_o u_z	velocity components	(m/s)
V	input volt	(V)
v_{r1},v_{r2}	radial inlet & outlet velocity	(m/s)
v_s	suction velocity	(m/s)
v_1, v_2	relative inlet & outlet velocity	(m/s)
W_p	water power	(W)
Z	number of impeller blades	

Greek Letters

α_1, α_2	vane inlet & outlet angle	(deg)
β_1, β_2	vane inlet & outlet angle	(deg)
γ	fluid specific weight	(kg/m^3)
θ	blade rotating angle	(deg)
η	overall efficiency	(%)
η_m	electric motor efficiency	(%)
η_{max}	pump maximum efficiency	(%)
ρ	fluid density	(kg/m^3)
φ	power factor of electric motor	
μ	dynamic viscosity	(kg/m.s)
μ_T	turbulent viscosity	

Abbreviations

2D	Two-Dimensional.
3D	Three-Dimensional.
B.C	Boundary condition
CFD	Computational Fluid Dynamics.
DS	Downstream.
max	Maximum value
NS	Navier-Stokes.
PS	Pressure Side.
SS	Suction Side.
US	Upstream.

List of figures